



# **NAVAL POSTGRADUATE SCHOOL**

**MONTEREY, CALIFORNIA**

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**MBA PROFESSIONAL REPORT**

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## **LOCATION OPTIMIZATION OF MOBILE COLD-FORMED STEEL SYSTEMS TO PROVIDE HUMANITARIAN RELIEF AFTER NATURAL DISASTERS**

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**December 2015**

**By: David M. Tully**

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**LOCATION OPTIMIZATION OF MOBILE COLD-FORMED STEEL SYSTEMS  
TO PROVIDE HUMANITARIAN RELIEF AFTER NATURAL DISASTERS**

David M. Tully, Lieutenant Commander, United States Navy

Submitted in partial fulfillment of the requirements for the degree of

**MASTER OF BUSINESS ADMINISTRATION**

from the

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December 2015**

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# **LOCATION OPTIMIZATION OF MOBILE COLD-FORMED STEEL SYSTEMS TO PROVIDE HUMANITARIAN RELIEF AFTER NATURAL DISASTERS**

## **ABSTRACT**

Cold-formed steel mobile factory (CFSMF) is a rapid self-contained system that produces members from rolled steel. The unit essentially provides a mobile framing construction system that can be used for construction of temporary, recyclable structures. These structures can be used for humanitarian assistance, disaster relief, and military contingency operations scenarios. CFSMF also provides benefits by reducing reliance on local economies' resources in natural disaster affected areas and areas that have internally displaced or emigrating persons for various reasons. This project discusses the benefits and potential uses of CFSMF and recommends global locations to base these units.

The 10 countries discussed in the case study have the highest need of such systems based on United Nations natural disaster data. The level of diplomatic relations of the 10 countries with the United States is gauged by the cumulative economic aid they received from the United States Agency for International Development (USAID) over a 10-year period. The recommended locations are determined by an integer programming optimization model. The model solution proposes an allocation method for CFSMF systems. The model can also be used for similar types of aid.

The case study in this report uses a small number of countries in order to simplify the mathematical model. It can be scaled up to reflect a larger set of countries, as well as additional types of constraints.

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## **LIST OF ACRONYMS AND ABBREVIATIONS**

|        |  |
|--------|--|
| AISI   | American Iron and Steel Institute                    |
| CAD    | computer aided design                                |
| CCP    | casualty collection points                           |
| CFS    | cold-formed steel                                    |
| CFSMF  | cold-formed steel mobile factory                     |
| CRED   | Centre for Research on the Epidemiology of Disasters |
| DOD    | Department of Defense                                |
| DRC    | disaster recovery center                             |
| EM-DAT | Emergency Events Database                            |
| HA/DR  | humanitarian assistance and disaster relief          |
| IP     | integer programming                                  |
| NGO    | nongovernmental organization                         |
| UN     | United Nations                                       |
| UNSD   | United Nations Statistics Division                   |
| USAID  | United States Agency for International Development   |

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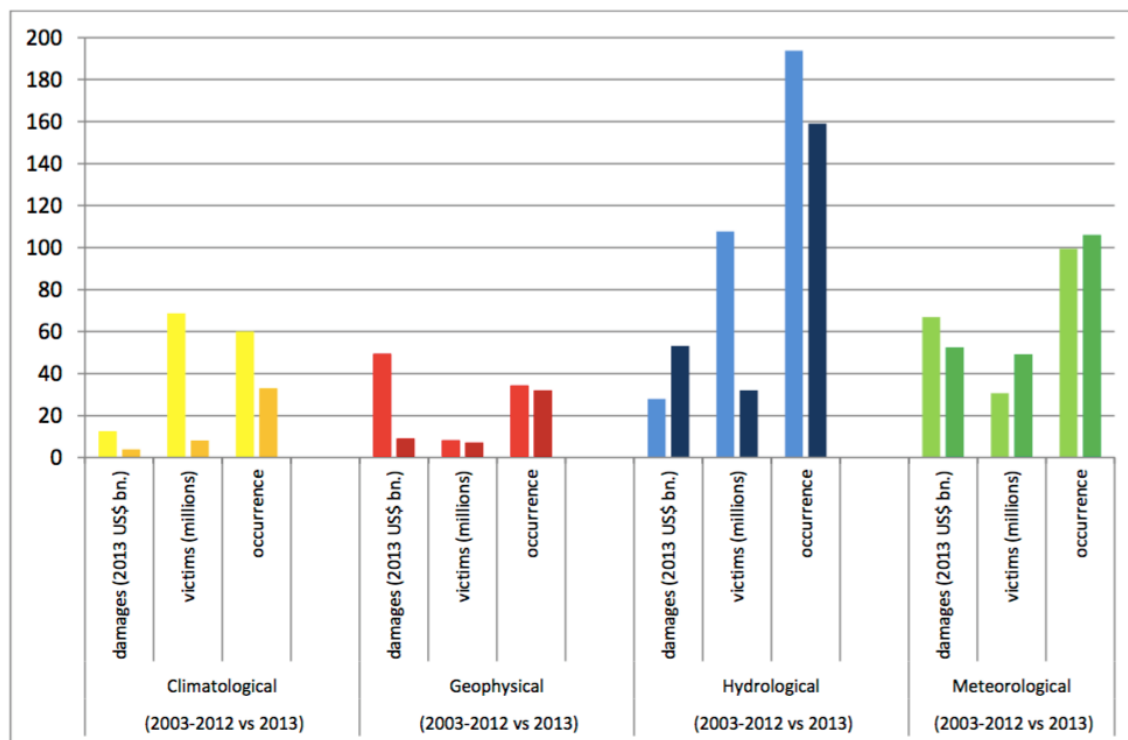
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# I. INTRODUCTION

## A. NATURAL DISASTERS

The Centre for Research on the Epidemiology of Disasters (CRED) defines a disaster as “a situation or event which overwhelms local capacity, necessitating a request to a national or international level for external assistance; an unforeseen and often sudden event that causes great damage, destruction and human suffering.” Examples include “floods, volcanic eruptions, earthquakes, tsunamis, and other geologic processes” (“Natural Disaster,” n.d.). Severity of the events are measured in economic loss, ability to rebuild and lives lost (Basic Planet, 2013). Natural disasters affect tens of millions of people, and cost tens of billions of dollars annually (see Figure 1).

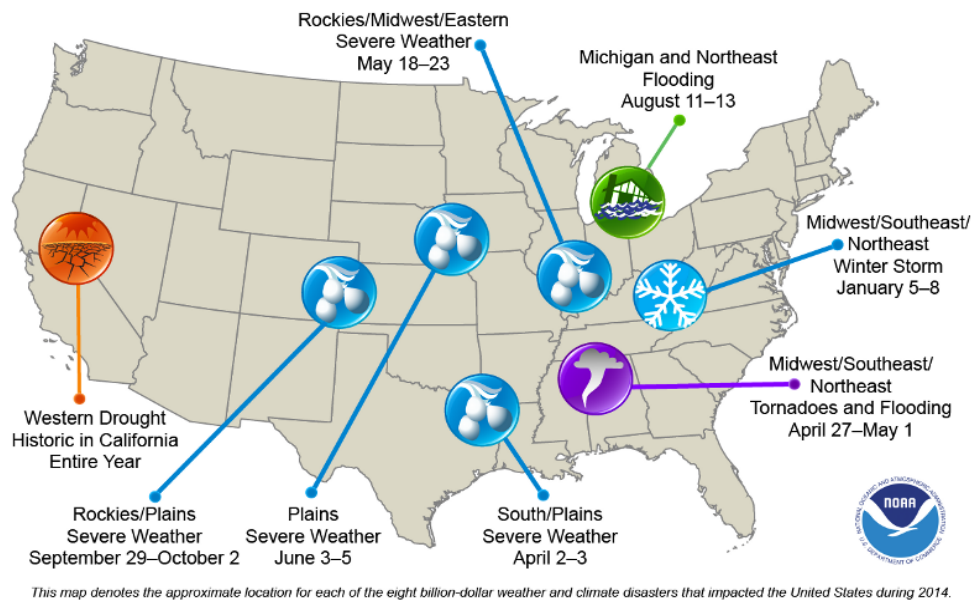
Figure 1. Natural Disaster Impacts by Disaster Subgroup, 2003–2012  
Annual Average versus 2013



Source: Guha-Sapir, D., Hoyois, P., & Below, R. (2014). Annual disaster statistical review 2013, the numbers and trends. Brussels: Centre for Research on the Epidemiology of Disasters. Retrieved from [http://www.disasters.ir/files/ADSR\\_2013.pdf](http://www.disasters.ir/files/ADSR_2013.pdf)

In 2014, the United States experienced eight natural disasters with financial losses of at least one billion dollars (see Figure 2) (National Centers for Environmental Information, n.d.).

Figure 2. U.S. 2014 Billion-Dollar Weather and Climate Disasters



Source: National Centers for Environmental Information, (n.d.). Billion-dollar weather and climate disasters; overview. Retrieved December 3, 2015, from <http://www.ncdc.noaa.gov/billions/>

The data on natural disasters used in this report was retrieved from the United Nations Statistics Division (USND) Environmental Indicators repository (“Environmental Indicators,” 2010). Country specific data regarding persons affected from various types of natural disasters is analyzed and the data is then used to influence decisions regarding allocation of cold-formed steel mobile factories (CFSMF) (see Figure 3) to affected countries.

## B. COLD-FORMED STEEL

Cold-formed steel (CFS) is a process where structural members are manufactured from steel sheeting that is shaped by roll forming machines (see Figure 4) at ambient temperatures and allows for high speed production and consistent quality of the members

(Cold-formed steel in building construction, 2010). CFS has its beginnings traced back to the California gold rush when Peter Naylor advertised “portable iron houses for California” (History, n.d.). Lustron Homes, an early mass manufacturer founded by Carl Strandlund, manufactured homes in the 1940s and sold about 2,500 homes with steel framing (History, n.d.). Two of the benefits of cold-formed steel are its cross-sections ability to maintain consistent thickness and its ability to carry heavy loads (History, n.d.).

Figure 3. FRAMECAD Cold-Formed Steel Mobile Factory



Courtesy of Brian Steckler, Department of Information Science, Naval Postgraduate School.

Figure 4. FRAMECAD Cold-Formed Steel Machine; Warehouse Configuration



Courtesy of Brian Steckler, Department of Information Science, Naval Postgraduate School.

The American Iron and Steel Institute (AISI), sponsored design specification development in 1939 and called upon George Winter of Cornell University (History, n.d.). His first published reports compiled the first edition of the AISI's "Specification for the Design of Light Gage Steel Structural Members" (History, n.d.).

Cold-formed steel features superior chemical and physical qualities that give it a broad range of advantages over other framing materials. According to the Steel Framing Industry Association, the advantages of cold-formed steel framing over other framing materials include the following:

**Strength:** Steel has the highest strength-to-weight ratio of any building material. Moreover, the strength of cold-formed steel also provides

architects with greater flexibility, allowing designs that incorporate longer spans and other architectural features.

**Durability:** Steel is inorganic, and thus impervious to termites, rot and mold. A protective layer of zinc and other metallic coating provides long-term durability that research demonstrates can last hundreds of years without any deterioration.

**Stability:** Due to its consistent chemistry, steel behaves in a highly predictable manner when subjected to the structural loads and stresses imposed by high wind and seismic forces. Because steel cannot absorb moisture, its use also eliminates most of the expansion and contraction of construction materials that produces cracks, warps, and other defects in both internal and external finishes.

**Non-combustibility:** Steel does not burn and will not contribute to the spread or intensity of a fire. Because of this, cold-formed steel projects can easily be designed to meet fire code rating requirements. Non-combustible structures, like those built with cold-formed steel framing, have a better loss history than combustible wood framing. This often translates into lower costs and broader coverage for many types of construction insurance.

**Sustainability:** Steel is the only building material that is infinitely recyclable. As a recognized green building material, cold-formed steel framing projects can earn credits for green building ratings such as LEED and similar programs.

**Cost-effectiveness:** Cold-formed steel offers cost savings on a number of fronts. By helping to minimize fire risk, the use of cold formed steel results in lower insurance costs for builders and owners. Additionally, panelized cold-formed steel construction methods produce shorter construction cycles, allowing builders to complete steel-framed projects months faster than with other framing materials. Finally, framing with cold-formed steel generates far less material waste than traditional wood framing. (Steel Framing Industry Association, n.d.)

While many advantages make CFS a desirable construction method for humanitarian assistance and disaster relief (HA/DR) purposes, it does have its disadvantages as well. The FRAMECAD unit that Tully and Skidmore (2015) evaluated costs \$421,000 (maintenance, support, spare parts, software, and training included in the figure), and is integrated into a 20-foot container box that requires transportation with heavy lift capability. The cost, weight, and shipping of the steel used by the machine must be taken into consideration, as well, as it will be incurred many times over the life

of the system. The high costs may be a limiting factor for government and non-government organizations that can benefit from the procurement of CFS systems.

Tully and Skidmore (2015) discuss utilizing cold-formed steel mobile factories in support of logistics in HA/DR operations. They suggest that CFSMF systems' capabilities decrease logistical burdens. In the wake of a disaster, reliance on local economies should be minimized. While re-building an economy, CFSMF systems can alleviate the struggles of local populations and ensure remaining natural resources are put to use for the host nation. Tully and Skidmore propose to conduct further research in order to determine the quantity and optimal locations of CFSMF systems globally.

### **C. RESEARCH QUESTIONS**

This thesis proposes a methodology that can be used as part of U.S. aid to countries affected by natural disasters. It is suggested here that the U.S., through the Department of Defense (DOD) or nongovernmental organizations (NGO), fund permanently stationed cold-formed steel mobile factories in countries that are significantly affected by natural disasters. This will enable the affected countries, DOD or NGOs to construct structures quickly and locally in the aftermath of a natural disaster.

The DOD and U.S. NGOs will benefit from the versatility of CFSMF. The CFSMF can be used to build; logistics support centers, barracks, operations centers, warehouses, and other structures to support areas affected by the natural disasters or for use at a base or staging location outside of the United States where DOD or NGOs have a presence.

Therefore, this report focuses on determining the optimal global quantities and locations of mobile CFSMF, such that the impact of these units is maximized over the areas on earth affected by four natural disaster categories (climatological, geophysical, hydrological, and meteorological) ("Environmental Indicators," 2010). The main factor affecting the quantity and allocation decisions for CFSMF systems is the number of persons affected by natural disaster events in each country. Additional modeled considerations include the level of diplomatic relations with the aided countries,

countries' own CFSMF availability, and logistics capabilities that allow sharing of CFSMF units among neighboring countries.

Specifically, this research intends to answer the following question: assuming that the U.S. is planning to directly purchase, through the DOD or provide economic aid to NGOs to purchase, a given number of cold formed steel mobile factories in foreign countries affected by natural disasters, what is the optimal quantity of CFSMF units allocated to each country considering the factors listed above?

#### **D. METHODOLOGY**

This report focuses on determining the optimal global allocation of CFSMFs, such that the impact of these units is maximized over the areas on earth affected by the four natural disaster categories. The factors affecting the quantity and location decisions for the CFSMF systems are as follows:

- the number of persons affected by natural disaster events in these locations
- the current level of aid to these countries
- the countries' own CFSMF availability
- the possibility of sharing CFSMF units among neighboring countries

It is important to note that the natural disaster data on affected persons in countries that have recorded natural disaster data is assumed to be non-overlapping. Therefore, if one type of natural disaster affected 100 persons and another type of natural disaster affected 200 persons, then the total number of affected persons is 300.

The countries affected by natural disasters of the four natural disaster categories in the 10-year period 2000–2009 were sorted by the number of persons affected by these disasters in descending order. The 10 countries with the highest number of persons affected were selected as a case study for analysis and modeling in this thesis.

The United States Agency for International Development (USAID) total economic aid to the 10 selected countries were rated such that the country receiving the most funds received a rating of 10. The remaining countries received a normalized rating.

Integer programming optimization models are often used to determine optimal allocation of limited resources. In order to determine the optimal allocation of a limited number of CFSMF units to the 10 countries an integer programming optimization model was developed.

Assumptions regarding availability of CFSMF units in each country and neighboring relationships that allow sharing of CFSMF units added constraints to the optimization model.

## II. DATA

### A. NATURAL DISASTER DATA

The natural disaster data was retrieved from the United Nations Statistical Division (USND) Environmental Indicators repository (“Environmental Indicators,” 2010). The source data is compiled by CRED and is maintained in the Emergency Events Database (EM-DAT). The UNSD Environmental Indicators website page divides natural disasters into four categories; climatological, geophysical, hydrological, and meteorological.

The following parameters from EM-DAT apply to all four natural disaster categories. According to the source data, “only disasters that fulfill at least one of the below criteria are included in EM-DAT” (“Climatological Disasters,” 2010):

- ten or more people reported killed
- one-hundred or more people reported affected
- declaration of a state of emergency
- call for international assistance

“Persons affected,” is the number of total affected according to the EM-DAT definitions. Total affected is the sum of injured, homeless, and affected. “Injured” is defined as people suffering from physical injuries, trauma or an illness requiring medical treatment as a direct result of a disaster. “Homeless” is defined as people needing immediate assistance for shelter. “Affected” is defined as people requiring immediate assistance during a period of emergency; it can also include displaced or evacuated people. (“Climatological disasters,” 2010)

A ‘0’ in EM-DAT does not represent a value and can mean either that there were no reported events or no information is available. (“Climatological disasters,” 2010)

**Data Quality;** the EM-DAT database is compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies. Priority is given to data from UN agencies, governments and the International Federation of Red Cross and Red Crescent Societies. The entries are constantly reviewed for redundancy, inconsistencies and incompleteness. CRED consolidates and

updates data on a daily basis. A further check is made at monthly intervals. Revisions are made annually at the end of each calendar year. (“Climatological Disasters,” 2010)

**Climatological disasters;** are defined as events caused by long-lived/meso to macro scale processes in the spectrum from intra-seasonal to multi-decadal climate variability. Such events are further classified as extreme temperature; drought; wildfire. Extreme temperature events are heat waves, cold waves and extreme winter conditions (snow pressure, icing, freezing rain, avalanche). Wildfire is forest fires and land fires (grass, scrub, bush, etc.). (“Climatological disasters,” 2010)

**Geophysical disasters;** are events originating from solid earth and are classified as, earthquakes (ground shaking and tsunamis), volcanic eruptions, and dry mass, movements (rock fall, avalanche, landslide, subsidence). (“Geophysical disasters,” 2010)

**Hydrological disasters;** defined by EM-DAT are events caused by deviations in the normal water cycle and/or overflow of bodies of water caused by wind set-up. Such events are further classified as, flood (river flood, flash flood, storm surge/coastal flood), and wet mass movement (rock fall). (“Hydrological disasters,” 2010)

**Meteorological disasters;** are defined by EM-DAT as events caused by short-lived/small to meso scale atmospheric processes (lasting minutes to days). Such events are classified as, tropical storms and extra-tropical cyclones (winter storms). (“Meteorological disasters,” 2010)

## **B. ECONOMIC AID DATA**

The economic aid data was retrieved from the United States Agency for International Development Greenbook (Greenbook, n.d.) for the most recent 10-year period (2003–2012). The economic aid data is used in this thesis as a measure of the diplomatic relations between the U.S. and foreign countries. Higher aid indicates not only higher need for aid, but also closer diplomatic relations.

## **C. DATA ANALYSIS**

### **1. Natural Disaster Data**

Natural disaster data from the climatological, geophysical, hydrological, and meteorological categories was deduced from the raw data and consolidated to total persons affected and number of natural disaster events for the 10-year range; 2000–2009.

The consolidated data was then sorted in descending order by number of persons affected. The 10 countries with the most persons affected were selected for the case study in this thesis. These countries are shown in Table 1, along with the total number of natural disaster events for the 10-year period from 2000–2009 and total number of persons affected by these disasters.

Table 1. Countries with Highest Number of Persons Affected by Natural Disasters and Corresponding Number of Events from 2000–2009

| Country      | Persons Affected | Number of Events |
|--------------|------------------|------------------|
| China        | 1,112,214,506    | 271              |
| India        | 598,790,757      | 153              |
| Bangladesh   | 71,698,450       | 63               |
| Philippines  | 49,768,870       | 141              |
| Thailand     | 28,072,184       | 37               |
| Ethiopia     | 22,831,949       | 29               |
| Vietnam      | 20,316,122       | 76               |
| South Africa | 15,102,150       | 17               |
| Pakistan     | 12,363,793       | 52               |
| Indonesia    | 10,098,137       | 137              |

Adapted from: Environmental Indicators. (2010). Retrieved October 21, 2014 from <http://unstats.un.org/unsd/environment/qindicators.htm>

## 2. Economic Aid Data

The data from each year of the 10-year period (2003-2012) was totaled for the 10 countries listed in Table 1. The 10 countries were then sorted in descending order of aid and listed in Table 2.

Table 2. Corresponding Natural Disaster Countries' Economic Aid Totals  
from USAID, 2003–2012, in Millions

| Country        | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | Total |
|----------------|------|------|------|------|------|------|------|------|------|------|-------|
| Pakistan       | 322  | 349  | 434  | 629  | 616  | 532  | 1339 | 2002 | 759  | 1138 | 8121  |
| Ethiopia       | 721  | 433  | 676  | 322  | 466  | 1004 | 960  | 989  | 552  | 865  | 6987  |
| South Africa   | 78   | 128  | 185  | 260  | 391  | 566  | 568  | 563  | 490  | 273  | 3503  |
| Indonesia      | 180  | 151  | 534  | 210  | 236  | 194  | 217  | 323  | 234  | 214  | 2493  |
| Philippines    | 109  | 109  | 98   | 113  | 103  | 127  | 153  | 209  | 586  | 166  | 1771  |
| India          | 176  | 178  | 194  | 170  | 153  | 146  | 143  | 168  | 106  | 174  | 1607  |
| Bangladesh     | 102  | 89   | 78   | 82   | 88   | 184  | 168  | 237  | 217  | 247  | 1492  |
| Thailand       | 5.2  | 8.3  | 19   | 23   | 26.1 | 32.9 | 36.8 | 40.8 | 39.6 | 45.8 | 278   |
| China (P.R.C.) | 3    | 1.6  | 3.1  | 11.2 | 24.7 | 29.5 | 14.7 | 40.8 | 9.7  | 12.5 | 151   |
| Vietnam        |      |      |      |      |      |      |      |      |      |      | 0     |

Adapted from: Greenbook. (n.d.). Retrieved April 3, 2015 from <https://explorer.usaid.gov/reports-greenbook.html>

Based on the data analysis of persons affected and total economic aid received, the 10 countries identified are the focus of the case study's integer programming model. The model will demonstrate how CFSMF allocation decisions can be made using the results of the analysis above.

### **III. LITERATURE REVIEW**

Natural disaster events create havoc, and having the proper assets available is imperative and an integral part of the HA/DR process. A CFSMF is one of those integral parts. The mobile factory has the ability to serve many purposes; command operations, triage facility, food or medicine dispersal center, shelter, etc., all secured within the confines of a CFS structure.

Apte, Heidtke, and Salmerón (2014) propose an optimization model to determine the locations of casualty collection points (CCP) after a nuclear device detonation within a specific geographic area. Their focus is to optimize the CCP locations in order to maximize casualty throughput with specific parameters for such an event for the District of Columbia. Their study stresses the importance of location optimization of CCP facilities as a part of the overall planning for a national security plan.

Dekle, Lavieri Martin, Emir-Farinas, and Francis (2005), utilized an integer programming solution known as a covering-facility-location model to optimize locations for disaster recovery centers (DRCs) in Alachua County, Florida. Their study required that each DRC in Alachua must be within 20 miles of each resident in the county with specific structure, communication, and parking requirements.

Yoho and Apte (2011) discuss a worldwide strategy to effectively and efficiently provide emergency supplies and services for HA/DR efforts after a natural disaster. They investigate prepositioning supplemental resources and preemptive and phased deployment of assets as potential policy options that could be correlated between the policies and disaster classification, which is based on localization of a disaster and speed of onset. Yoho and Apte's (2011) discussion is focused on policies and disaster types.

Caunhye, Nie and Pokharel (2012) classify optimization models in HA/DR operations, which are used in times of emergency logistics. The study identifies classes to include facility location, relief distribution, casualty transportation, and other operations. The authors identify research gaps and propose future directions.

Anderson (1970) discusses the importance of military assistance in natural disasters as the military is seasoned in rapid response. Yoho and Apte (2011) discuss a related expertise of the U.S. military to aid in conflict response and prepositioning. Both prepositioning and quick response are hallmarks of U.S. military operations.

Sobel and Leeson (2007) discuss centralized information in disaster relief as a factor in the relief success or failure. CFSMF systems allow users to incorporate fragmented information (Sobel & Leeson, 2007) to meet the current needs of HA/DR efforts. Fawcett and Fawcett (2013) discuss the systems design aspect of HA/DR supply chains, moving, eventually, to a synchronized supply chain from a temporary one to increase effectiveness.

Balcik and Beamon (2008) utilize a covering location model to determine where to locate facilities in a HA/DR supply chain. Much like this study, their research determines the optimal quantities and locations of distribution warehouses. Their study also determines optimal quantities of specific supplies in the centers.

Brandeau and Chiu (1989) review 50 representative problems in location research and conclude that most of these problems are solved using optimization models.

Risk is involved in most operations and the management and understanding of risk is necessary. Nolz, Semet, and Doerner (2011) solve a multi-objective optimization problem for distribution of supplies in HA/DR operations. They focus on the risk involved in using transportation routes that become impassable after a disaster event. The research utilizes data from Manabi province, Ecuador.

## IV. MODEL METHODOLOGY

### A. MODEL SELECTION

The data collected indicates that multiple objectives should affect the decision of allocating CFS units to countries. The objectives considered are as follows:

- Aid provided to countries based on the severity of the natural disasters they suffer.
- Level of aid should be consistent with level of diplomatic relationship with the U.S.
- More aid should be provided to countries that have lower capabilities to aid themselves after disasters.
- Neighboring countries may be able to share aid depending on the severity of disasters.
- Total aid should not exceed budget limits.

In the context of supplying CFSMF system to countries that suffer natural disasters, the allocation decision of CFSMF systems to the various countries can be viewed as a multiple-objective optimization problem. Since the number of CFSMF systems allocated to a country must be an integer, the allocation model developed here is an integer programming (IP) optimization model. The various objectives are modeled here either as utilities (weights), or as bounds (constraints).

The utility of allocating a CFSMF system to a country can be estimated or evaluated in multiple ways. In this thesis, the utility measure used is a combination of the country's need and its relationship with the United States. More specifically,  $U_i$  - the utility parameter for country (i), is the sum of the percentage of persons affected by natural disasters in country (i), and the percentage of economic aid to country (i). These percentages are displayed in Table 3 and Table 4, respectively.

For example, the utility parameter for China is 0.5787, which is the sum of the percentage of persons affected by natural disasters in China (0.573), and the percentage of economic aid to China (0.0057).

Clearly, this method for utility parameter calculation can be much more sophisticated and include many more considerations at various levels of importance. A more sophisticated utility parameter calculation can be the responsibility of U.S. government agencies, such as the Department of State.

Table 3. Persons Affected in Each Country as a Percentage of the Total Persons Affected from the Sample Countries

| Country      | Persons Affected | %     |
|--------------|------------------|-------|
| China        | 1112214506       | 0.573 |
| India        | 598790757        | 0.308 |
| Bangladesh   | 71698450         | 0.037 |
| Philippines  | 49768870         | 0.026 |
| Thailand     | 28072184         | 0.014 |
| Ethiopia     | 22831949         | 0.012 |
| Vietnam      | 20316122         | 0.010 |
| South Africa | 15102150         | 0.008 |
| Pakistan     | 12363793         | 0.006 |
| Indonesia    | 10098137         | 0.005 |
| Total        | 1941256918       | 1     |

Adapted from: Environmental indicators. (2010). Retrieved October 21, 2014 from <http://unstats.un.org/unsd/environment/qindicators.htm>

Table 4. Percentage of Economic Aid Received by Each Country as a Percentage of the Total Economic Aid Distributed Among the Sample Countries

| Country        | Aid (in millions) | %      |
|----------------|-------------------|--------|
| China (P.R.C.) | 151               | 0.0057 |
| India          | 1607              | 0.0609 |
| Bangladesh     | 1492              | 0.0565 |
| Philippines    | 1771              | 0.0671 |

| Country      | Aid (in millions) | %      |
|--------------|-------------------|--------|
| Thailand     | 278               | 0.0105 |
| Ethiopia     | 6987              | 0.2646 |
| Vietnam      | 0                 | 0      |
| South Africa | 3503              | 0.1327 |
| Pakistan     | 8121              | 0.3076 |
| Indonesia    | 2493              | 0.0944 |
| Total        | 26403             | 1      |

Adapted from: Greenbook. (n.d.). Retrieved April 3, 2015 from <https://explorer.usaid.gov/reports-greenbook.html>

## B. INTEGER PROGRAMMING MODEL

Decisions: Determine how many CFS units should be allocated to each country.

### 1. Decision Variables

$X_i$  = Number of CFS units to allocate to country (i)

i = 1(China), 2(India), 3(Bangladesh), 4(Philippines), 5(Thailand), 6(Ethiopia), 7(Vietnam), 8(South Africa), 9(Pakistan), 10(Indonesia)

### 2. Objective Function: Maximize the Total Allocation Utility Achieved

$$\sum_i U_i X_i \quad (1)$$

### 3. Constraints

Upper limit on total CFS units:

$$\sum_i X_i \leq 30 \quad (2)$$

Upper Limit of 2 on CFS Units to China:

$$X_1 \leq 2 \quad (3)$$

Upper Limit of 4 on CFS Units to every other country:

$$X_i \leq 4 \text{ for } i=2,3,\dots,10 \quad (4)$$

Upper Limit of 6 on combined CFS systems to the neighboring countries India and Pakistan:

$$X_2 + X_9 \leq 6 \quad (5)$$

*Non-negativity and Integrality:*

$$X_i \geq 0 \text{ and Integer} \quad (6)$$

Figure 5. Excel Solver Results.

| China       | India       | Bangladesh  | Philippines | Thailand    | Ethiopia    | Vietnam     | S. Africa  | Pakistan    | Indonesia   |             |        |
|-------------|-------------|-------------|-------------|-------------|-------------|-------------|------------|-------------|-------------|-------------|--------|
| X1          | X2          | X3          | X4          | X5          | X6          | X7          | X8         | X9          | X10         |             |        |
| 2           | 4           | 4           | 4           | 2           | 4           | 0           | 4          | 2           | 4           | 6.122954464 |        |
| 0.578654291 | 0.369319478 | 0.093442765 | 0.092713157 | 0.024989935 | 0.276390445 | 0.010465447 | 0.14045389 | 0.313947647 | 0.099622944 | Allocation  | Limits |
| 1           | 1           | 1           | 1           | 1           | 1           | 1           | 1          | 1           | 1           | 30          | 30     |
| 1           |             |             |             |             |             |             |            |             |             | 2           | 2      |
|             | 1           |             |             |             |             |             |            |             |             | 4           | 4      |
|             |             | 1           |             |             |             |             |            |             |             | 4           | 4      |
|             |             |             | 1           |             |             |             |            |             |             | 4           | 4      |
|             |             |             |             | 1           |             |             |            |             |             | 4           | 4      |
|             |             |             |             |             | 1           |             |            |             |             | 2           | 4      |
|             |             |             |             |             |             | 1           |            |             |             | 4           | 4      |
|             |             |             |             |             |             |             | 1          |             |             | 0           | 4      |
|             |             |             |             |             |             |             |            | 1           |             | 4           | 4      |
|             |             |             |             |             |             |             |            |             | 1           | 2           | 4      |
|             |             |             |             |             |             |             |            |             | 1           | 4           | 4      |
|             | 1           |             |             |             |             |             |            | 1           |             | 6           | 6      |

#### 4. Results

After solving the problem using Excel Solver, the results are listed in Table 5:

Table 5. Number of CFS Systems Allocated to Each Country

| Country        | No. of Systems |
|----------------|----------------|
| China (P.R.C.) | 2              |
| India          | 4              |
| Bangladesh     | 4              |
| Philippines    | 4              |
| Thailand       | 2              |
| Ethiopia       | 4              |
| Vietnam        | 0              |
| South Africa   | 4              |
| Pakistan       | 2              |
| Indonesia      | 4              |

## **V. CONCLUSION AND FURTHER RESEARCH**

### **A. CONCLUSIONS**

The research of this paper focused on the optimal allocation of CFSMF to countries affected by natural disasters. Several factors were considered in the allocation model. The main two factors were the worldwide natural disaster events (climatological, geophysical, hydrological, and meteorological) for the 10-year period, 2000–2009 (“Environmental indicators,” 2010), and total economic aid obligated by USAID to foreign nations in the form of loans or grants (Greenbook, n.d.) for the 10-year period, 2003–2012. The raw data was sorted in descending order to obtain a ranking of countries based on number of persons affected by natural disasters over the 10-year period. The data was used in the integer programming optimization model to allocate a hypothetical number (30) of cold-formed steel mobile factory units to the countries with the most persons affected by natural disasters. To convert the total persons affected in each country to a percentage, the 10-year total persons affected in each country was divided by the 10-year total persons affected of the sample 10 countries that comprise persons affected (see Table 3). Similar steps were used to calculate the percentage of the total USAID economic aid obligated to each country in the 10-country sample (see Table 4). These percentages were added to achieve a utility parameter that represented the benefit to each country from each of the hypothetical 30 cold-formed steel mobile factory systems available for distribution by the United States.

In this optimization model, the objective was to maximize the total allocation utility of the cold-formed steel units. China, a country with a robust industrial base, had an upper limit of 2 CFSMF systems, as it is hypothesized that China has its own CFSMF systems, as well as sufficient means to aid displaced persons in the event of a natural disaster. All other countries (except India and Pakistan) were constrained to an upper limit of 4 CFSMF systems, whereas India and Pakistan’s constraint had a combined upper limit of 6 CFSMF systems. The reason for India and Pakistan having a combined upper limit of 6 is due to the two countries sharing a border and the assumption that, if needed, CFSMF systems can be transported between the two countries. This, of course, is

dependent on transportation routes being passable. The solution produced by Excel Solver is the recommendation to distribute the hypothetical 30 units to the 10 countries in the sample set.

## **B. RECOMMENDATIONS**

This study identifies the countries that are in most need of CFSMF based on persons affected and economic aid received and ultimately recommends the DOD purchase and maintain 20 CFSMF. These systems can be used by the DOD for HA/DR operations and the units will also be available for user training, DOD contingency operations, base support, training, or shipboard basing (Tully & Skidmore, 2015) among others.

The remaining 10 units will be purchased through USAID for NGOs that operate in the 10 countries identified. The NGOs will be able to use the units for HA/DR operations as well as for reinforcing the areas with sound structures to better prepare the communities in the event of another natural disaster strike.

## **C. AREAS FOR FURTHER RESEARCH**

Tully and Skidmore's (2015) analysis suggested that the cold-formed steel mobile factory systems could be a powerful asset in the humanitarian response to assist persons affected after natural disasters. Their evaluation of the operation of a CFSMF in an austere environment showed that the unit did have validity as part of the logistical response to a humanitarian disaster. Their evaluation was not conducted during an actual response to a disaster. However, it was conducted in an area that is susceptible to natural disasters. Further research of the performance of CFS systems during an actual response to a natural disaster is needed to determine if CFSMF can be a viable and integral part of disaster response. Results of this research can be used to determine the validity of a CFSMF for use by disaster aid organizations, military organizations, and governments, in order to assist displaced persons.

Another area for further research and testing includes identifying candidate areas for prepositioning of CFSMF systems. For example, several key areas of the world that

are prone to natural disaster events are located in Asia. In this case study 8 of the 10 countries identified from the UNSD (“Environmental indicators,” 2010) are in Asia. It is recommended that prepositioning sites be chosen such that handling heavy lift via aerial or seaports and adequate roads for easy transportation and distribution of the units are available.

Additional research will also be needed to determine an appropriate set of parameters for the model, requiring not only research into various countries’ capabilities, but also a political discussion regarding diplomatic relations and political preferences. As stated in this report, the case study provided here used simplistic, although partially supported by United Nations (UN) and USAID data, considerations.

Further research may also identify additional types of asset allocation decisions, such as allocation of emergency supply distribution centers, for which the proposed optimization model can be used. The model and the methodology described in this report can be utilized even if the discussed assets and the factors affecting the allocation decisions vary.

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## APPENDIX A. UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT RAW DATA

Table 6. USAID Foreign Economic Aid (Grants and Loans), 2003–2012

| Country          | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|------------------|------|------|------|------|------|------|------|------|------|------|
| Iraq             | 3782 | 7551 | 6292 | 4226 | 3693 | 3168 | 3082 | 1022 | 1142 | 784  |
| Afghanistan      | 642  | 1433 | 1507 | 1352 | 1924 | 2696 | 2823 | 4498 | 2667 | 3326 |
| Russia           | 695  | 879  | 1499 | 1386 | 1487 | 1372 | 478  | 439  | 904  | 339  |
| Pakistan         | 322  | 349  | 434  | 629  | 616  | 532  | 1339 | 2002 | 759  | 1138 |
| Sudan            | 188  | 477  | 884  | 757  | 806  | 1001 | 1214 | 890  | 524  | 298  |
| Ethiopia         | 721  | 433  | 676  | 322  | 466  | 1004 | 960  | 989  | 552  | 865  |
| Colombia         | 604  | 466  | 567  | 1112 | 161  | 677  | 717  | 684  | 286  | 544  |
| Kenya            | 123  | 174  | 254  | 389  | 509  | 715  | 926  | 815  | 865  | 746  |
| Jordan           | 1035 | 359  | 355  | 309  | 307  | 573  | 582  | 464  | 536  | 832  |
| Haiti            | 83   | 162  | 224  | 210  | 206  | 306  | 371  | 1417 | 1198 | 510  |
| West Bank/Gaza   | 191  | 134  | 347  | 85   | 152  | 519  | 1052 | 697  | 469  | 457  |
| Egypt            | 412  | 653  | 232  | 443  | 634  | 187  | 593  | 367  | 172  | 103  |
| Tanzania         | 80   | 97   | 133  | 187  | 237  | 1062 | 378  | 494  | 453  | 399  |
| South Africa     | 78   | 128  | 185  | 260  | 391  | 566  | 568  | 563  | 490  | 273  |
| Uganda           | 177  | 216  | 288  | 278  | 364  | 453  | 482  | 470  | 323  | 349  |
| Nigeria          | 91   | 131  | 150  | 186  | 339  | 483  | 499  | 460  | 441  | 331  |
| Mozambique       | 92   | 99   | 104  | 145  | 253  | 776  | 342  | 420  | 273  | 274  |
| Indonesia        | 180  | 151  | 534  | 210  | 236  | 194  | 217  | 323  | 234  | 214  |
| Congo (Kinshasa) | 112  | 116  | 119  | 177  | 142  | 247  | 328  | 357  | 403  | 371  |
| Israel           | 657  | 557  | 482  | 286  | 168  | 44   | 40   | 36   | 37   | 25   |
| Zambia           | 66   | 100  | 142  | 191  | 203  | 263  | 298  | 338  | 287  | 222  |
| Georgia          | 87   | 110  | 96   | 397  | 89   | 111  | 613  | 404  | 88   | 78   |
| Mexico           | 53   | 83   | 92   | 168  | 72   | 83   | 431  | 624  | 335  | 118  |
| Peru             | 254  | 252  | 171  | 305  | 107  | 150  | 146  | 194  | 133  | 102  |
| Philippines      | 109  | 109  | 98   | 113  | 103  | 127  | 153  | 209  | 586  | 166  |
| Ghana            | 74   | 71   | 71   | 104  | 608  | 89   | 127  | 210  | 150  | 209  |
| Ukraine          | 88   | 126  | 152  | 141  | 165  | 119  | 178  | 304  | 209  | 207  |
| Liberia          | 45   | 118  | 121  | 123  | 199  | 133  | 169  | 275  | 248  | 234  |
| India            | 176  | 178  | 194  | 170  | 153  | 146  | 143  | 168  | 106  | 174  |
| Bangladesh       | 102  | 89   | 78   | 82   | 88   | 184  | 168  | 237  | 217  | 247  |
| Senegal          | 46   | 50   | 46   | 66   | 68   | 75   | 147  | 696  | 138  | 138  |
| Mali             | 52   | 55   | 52   | 60   | 527  | 83   | 155  | 184  | 197  | 93   |
| Bolivia          | 249  | 173  | 157  | 214  | 143  | 126  | 99   | 98   | 73   | 34   |
| Zimbabwe         | 31   | 30   | 60   | 30   | 140  | 232  | 286  | 223  | 163  | 153  |
| Somalia          | 31   | 31   | 41   | 103  | 82   | 305  | 180  | 64   | 202  | 275  |
| Rwanda           | 47   | 59   | 75   | 104  | 121  | 172  | 175  | 230  | 159  | 155  |

| Country               | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|-----------------------|------|------|------|------|------|------|------|------|------|------|
| Lebanon               | 67   | 36   | 24   | 144  | 192  | 190  | 155  | 158  | 115  | 141  |
| Malawi                | 39   | 55   | 80   | 73   | 101  | 105  | 142  | 213  | 209  | 153  |
| Chad                  | 7    | 59   | 60   | 82   | 97   | 127  | 223  | 174  | 151  | 157  |
| Guatemala             | 82   | 70   | 64   | 104  | 81   | 108  | 143  | 165  | 153  | 130  |
| Morocco               | 22   | 21   | 36   | 34   | 72   | 701  | 38   | 56   | 50   | 37   |
| El Salvador           | 57   | 56   | 48   | 49   | 501  | 50   | 49   | 106  | 85   | 47   |
| Namibia               | 31   | 31   | 49   | 64   | 91   | 132  | 395  | 105  | 71   | 67   |
| Micronesia            | 100  | 95   | 94   | 100  | 100  | 79   | 108  | 90   | 135  | 97   |
| Kazakhstan            | 61   | 72   | 62   | 109  | 90   | 112  | 92   | 162  | 90   | 76   |
| Honduras              | 69   | 61   | 284  | 84   | 57   | 64   | 25   | 102  | 90   | 77   |
| Armenia               | 79   | 72   | 69   | 315  | 73   | 68   | 60   | 77   | 47   | -21  |
| Angola                | 165  | 118  | 67   | 57   | 53   | 58   | 56   | 101  | 86   | 68   |
| Nepal                 | 52   | 50   | 70   | 61   | 79   | 106  | 87   | 82   | 106  | 121  |
| Botswana              | 14   | 20   | 41   | 43   | 214  | 210  | 103  | 61   | 44   | 58   |
| Burkina Faso          | 15   | 18   | 33   | 21   | 28   | 47   | 506  | 35   | 41   | 60   |
| Cambodia              | 62   | 73   | 69   | 68   | 74   | 75   | 83   | 95   | 19   | 143  |
| South Sudan           |      |      |      |      |      |      |      |      | 344  | 396  |
| Yemen                 | 39   | 58   | 16   | 36   | 25   | 32   | 57   | 125  | 79   | 237  |
| Kosovo                |      |      |      |      |      | 209  | 138  | 176  | 100  | 76   |
| Sri Lanka             | 28   | 36   | 153  | 47   | 40   | 71   | 85   | 122  | 81   | 26   |
| Nicaragua             | 66   | 59   | 87   | 246  | 52   | 60   | 35   | -14  | 66   | 26   |
| Madagascar            | 47   | 45   | 155  | 53   | 63   | 65   | 55   | 59   | 74   | 66   |
| Benin                 | 30   | 29   | 25   | 23   | 327  | 39   | 45   | 56   | 50   | 37   |
| Cote d'Ivoire         | 25   | 34   | 40   | 36   | 87   | 79   | 90   | 79   | 74   | 94   |
| Moldova               | 41   | 46   | 31   | 25   | 49   | 24   | 32   | 307  | 31   | 29   |
| China (P.R.C.)        | 28   | 38   | 40   | 46   | 57   | 100  | 63   | 97   | 87   | 60   |
| Lesotho               | 3    | 5    | 4    | 4    | 44   | 365  | 30   | 46   | 45   | 27   |
| Niger                 | 14   | 20   | 25   | 34   | 38   | 50   | 44   | 131  | 79   | 134  |
| Serbia and Montenegro | 186  | 166  | 211  | 5    |      |      |      |      |      |      |
| Kyrgyzstan            | 55   | 39   | 43   | 36   | 37   | 50   | 52   | 114  | 60   | 77   |
| Serbia                |      |      |      | 124  | 126  | 65   | 60   | 68   | 59   | 33   |
| Mongolia              | 21   | 28   | 16   | 12   | 12   | 324  | 36   | 39   | 20   | 25   |
| Dominican Republic    | 37   | 41   | 33   | 40   | 50   | 52   | 69   | 89   | 61   | 59   |
| Marshall Islands      | 47   | 42   | 45   | 51   | 48   | 48   | 49   | 20   | 100  | 70   |
| Azerbaijan            | 58   | 58   | 57   | 50   | 54   | 38   | 51   | 54   | 50   | 31   |
| Burundi               | 44   | 49   | 59   | 49   | 37   | 47   | 65   | 54   | 53   | 44   |
| Thailand              | 20   | 12   | 43   | 43   | 47   | 49   | 62   | 79   | 70   | 74   |
| Ecuador               | 82   | 72   | 66   | 51   | 36   | 30   | 21   | 43   | 57   | 21   |
| Tajikistan            | 48   | 49   | 54   | 39   | 31   | 43   | 49   | 74   | 36   | 37   |
| Bosnia & Herzegovina  | 64   | 50   | 35   | 42   | 34   | 36   | 49   | 48   | 51   | 39   |

| Country                  | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|--------------------------|------|------|------|------|------|------|------|------|------|------|
| Albania                  | 42   | 52   | 39   | 49   | 31   | 44   | 35   | 37   | 33   | 31   |
| Guinea                   | 49   | 53   | 41   | 36   | 32   | 26   | 30   | 27   | 34   | 39   |
| Uzbekistan               | 88   | 45   | 44   | 48   | 18   | 15   | 18   | 31   | 19   | 34   |
| Korea, North             | 37   | 57   | 8    | 1    | 24   | 206  | 11   | 5    | 2    | 3    |
| Macedonia                | 55   | 39   | 43   | 38   | 32   | 30   | 30   | 34   | 33   | 19   |
| Brazil                   | 40   | 24   | 46   | 37   | 20   | 35   | 43   | 33   | 44   | 21   |
| Jamaica                  | 24   | 39   | 62   | 34   | 32   | 21   | 26   | 36   | 33   | 17   |
| Timor-Leste              | 24   | 19   | 26   | 25   | 29   | 34   | 36   | 46   | 27   | 37   |
| Burma (Myanmar)          | 4    | 9    | 11   | 10   | 17   | 87   | 29   | 33   | 32   | 56   |
| Poland                   | 0    | 4    | 6    | 5    | 5    | 5    | 53   | 166  | 18   | 23   |
| Eritrea                  | 96   | 86   | 88   | 6    | 3    | 3    | 0    | 0    | 0    | -1   |
| Sierra Leone             | 42   | 33   | 27   | 21   | 18   | 11   | 26   | 37   | 25   | 21   |
| Paraguay                 | 13   | 18   | 13   | 52   | 16   | 15   | 56   | 36   | 21   | 16   |
| Canada                   | 24   | 21   | 21   | 23   | 24   | 27   | 26   | 26   | 27   | 23   |
| Romania                  | 40   | 40   | 47   | 36   | 19   | 13   | 10   | 11   | 9    | 9    |
| Syria                    | 0    | 0    | 0    | 3    | 8    | 44   | 19   | 22   | 26   | 107  |
| Bulgaria                 | 35   | 33   | 37   | 28   | 17   | 20   | 14   | 13   | 13   | 17   |
| Palau                    | 14   | 14   | 13   | 15   | 14   | 14   | 14   | 69   | 48   | 13   |
| Libya                    |      | 0    | 0    | 25   | 4    | 10   | 11   | 24   | 88   | 64   |
| Guyana                   | 10   | 20   | 23   | 21   | 31   | 30   | 23   | 19   | 17   | 9    |
| Panama                   | 17   | 21   | 18   | 27   | 24   | 12   | 28   | 34   | 11   | 9    |
| Belarus                  | 9    | 6    | 14   | 10   | 17   | 13   | 18   | 41   | 33   | 28   |
| Swaziland                | 1    | 3    | 2    | 3    | 8    | 14   | 23   | 47   | 38   | 41   |
| Mauritania               | 20   | 12   | 22   | 13   | 12   | 24   | 16   | 15   | 13   | 30   |
| Cape Verde               | 6    | 7    | 9    | 119  | 3    | 5    | 6    | 4    | 7    | 9    |
| Cameroon                 | 16   | 13   | 13   | 10   | 6    | 20   | 24   | 22   | 20   | 31   |
| Ireland                  | 50   |      | 37   |      | 27   |      | 30   | 0    | 17   | 3    |
| Cuba                     | 8    | 9    | 15   | 18   | 12   | 34   | 21   | 17   | 15   | 11   |
| Malaysia                 | 1    | 0    | 3    | 2    | 5    | 51   | 38   | 34   | 17   | 9    |
| Croatia                  | 35   | 27   | 31   | 16   | 15   | 6    | 4    | 4    | 8    | 3    |
| Tunisia                  | 0    | 0    | 0    | 0    | 1    | 1    | 1    | 1    | 17   | 129  |
| Turkey                   | 8    | 10   | 16   | 5    | 13   | 12   | 15   | 23   | 14   | 21   |
| China (Taiwan)           | 0    | 0    | 1    | 2    | 43   | 21   | 32   | 23   | 7    | 2    |
| Djibouti                 | 8    | 24   | 4    | 9    | 5    | 8    | 10   | 21   | 27   | 11   |
| Central African Republic | 1    | 2    | 2    | 4    | 21   | 18   | 22   | 19   | 18   | 22   |
| Turkmenistan             | 9    | 8    | 7    | 10   | 14   | 15   | 12   | 19   | 10   | 12   |
| Cyprus                   | 1    | 4    | 36   | 8    | 14   | 17   | 10   | 16   | 9    | 1    |
| Japan                    | 0    | 0    | 1    | 0    | 0    | 4    | 1    | 1    | 94   | 4    |
| Venezuela                | 10   | 12   | 9    | 10   | 8    | 19   | 6    | 11   | 5    | 9    |
| Hungary                  | 2    | 6    | 7    | 7    | 9    | 31   | 6    | 9    | 2    | 17   |
| Vanuatu                  | 2    | 2    | 2    | 70   | 4    | 4    | 4    | 2    | 3    | 2    |

| Country              | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|----------------------|------|------|------|------|------|------|------|------|------|------|
| Czech Republic       | 1    | 2    | 3    | 10   | 30   | 6    | 7    | 19   | 12   | 4    |
| Montenegro           |      |      |      | 15   | 11   | 12   | 10   | 16   | 13   | 4    |
| Congo (Brazzaville)  | 5    | 6    | 2    | 14   | 11   | 3    | 5    | 18   | 5    | 13   |
| Belgium              |      | 0    | 1    |      | 32   | 24   | 12   | 7    | 5    | 0    |
| Algeria              | 3    | 3    | 2    | 3    | 4    | 12   | 11   | 15   | 10   | 11   |
| Laos                 | 7    | 5    | 5    | 3    | 3    | 7    | 7    | 15   | 13   | 8    |
| Costa Rica           | 3    | 4    | 4    | 5    | 6    | 6    | 8    | 11   | 9    | 8    |
| Guinea-Bissau        | 2    | 0    | 15   | 5    | 6    | 1    | 2    | 8    | 3    | 14   |
| Latvia               | 1    | 2    | 2    | 6    | 11   | 7    | 4    | 3    | 12   | 4    |
| Estonia              | 1    | 3    | 3    | 3    | 2    | 10   | 11   | 7    | 9    | 5    |
| Argentina            | 1    | 2    | 1    | 2    | 8    | 3    | 3    | 6    | 18   | 6    |
| Gambia, The          | 4    | 3    | 2    | 5    | 2    | 12   | 5    | 7    | 3    | 3    |
| Chile                | 1    | 2    | 2    | 1    | 1    | 3    | 6    | 26   | 2    | 3    |
| Oman                 |      | 0    | 0    | 1    | 1    | 17   | 11   | 4    | 5    | 6    |
| Togo                 | 6    | 4    | 3    | 3    | 8    | 3    | 5    | 4    | 4    | 3    |
| Spain                |      |      | 0    |      | 2    | 0    | 2    | 16   | 18   | 1    |
| Lithuania            | 2    | 5    | 4    | 2    | 5    | 3    | 1    | 1    | 4    | 11   |
| Bahamas, The         | 1    | 2    | 2    | 1    | 2    | 7    | 3    | 8    | 6    | 3    |
| Iran                 | 2    | 10   | 1    | 3    | 5    | 3    | 1    | 1    | 1    | 1    |
| Slovakia             | 1    | 1    | 9    | 2    | 2    | 6    | 2    | 1    | 1    | 1    |
| Korea, South         | 0    |      | 1    | 0    | 14   | 6    | 2    | 1    | 1    | 1    |
| United Kingdom       |      | 0    |      | 0    | 20   | 2    | 1    | 1    | 1    | 1    |
| Belize               | 2    | 2    | 2    | 2    | 2    | 2    | 3    | 5    | 2    | 2    |
| Papua New Guinea     |      | 0    | 0    | 0    | 2    | 3    | 3    | 4    | 3    | 6    |
| Gabon                | 3    | 3    | 2    | 1    | 1    | 0    | 1    | 1    | 2    | 5    |
| Singapore            |      | 0    | 0    | 0    | 7    | 1    | 8    | 1    | 1    | 1    |
| United Arab Emirates |      | 0    | 1    | 1    | 11   | 1    | 1    | 1    | 3    | 0    |
| Fiji                 | 1    | 2    | 1    | 2    | 1    | 2    | 3    | 2    | 2    | 2    |
| Portugal             | 0    | 0    | 0    | 0    | 0    | 1    | 10   | 3    | 1    | 0    |
| Slovenia             | 0    | 1    | 4    | 1    | 3    | 1    | 2    | 2    | 1    | 0    |
| Austria              |      |      |      |      |      | 6    | 4    | 3    | 1    | 0    |
| Suriname             | 1    | 1    | 1    | 1    | 1    | 1    | 2    | 2    | 2    | 1    |
| Samoa                | 1    | 1    | 1    | 1    | 1    | 1    | 1    | 2    | 1    | 1    |
| Qatar                | 0    |      | 2    | 1    | 1    | 0    | 4    | 3    | 0    | 0    |
| Sao Tome & Principe  | 0    | 1    | 0    | 0    | 0    | 9    | 0    | 0    | 0    | 0    |
| Tonga                | 1    | 1    | 1    | 1    | 1    | 1    | 2    | 1    | 1    | 1    |
| Saudi Arabia         | 0    | 0    | 1    | 2    | 1    | 1    | 1    | 1    | 2    | 2    |
| Malta                |      | 0    |      | 1    | 1    | 0    |      | 0    | 5    | 1    |
| Barbados             | 0    | 1    | 2    | 3    | 0    | 0    | 0    | 1    | 0    | 1    |
| Bahrain              | 0    | 0    | 2    | 1    | 1    | 1    | 0    | 1    | 1    | 1    |

| Country                       | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|-------------------------------|------|------|------|------|------|------|------|------|------|------|
| Trinidad & Tobago             | 0    | 2    | 0    | 0    | 1    | 1    | 1    | 0    | 0    | 0    |
| Kiribati                      | 1    | 1    | 1    | 1    | 1    | 1    | 0    | 0    | 0    |      |
| Uruguay                       | 0    | 1    | 1    |      | 1    | 1    | 1    | 1    | 1    | 1    |
| China (Hong Kong)             | 1    | 0    | 0    | 0    | 0    | 0    | 1    | 2    | 0    | 1    |
| Mauritius                     | 0    | 0    | 1    | 0    | 1    | 0    | 0    | 0    | 1    | 0    |
| France                        |      |      |      |      |      | 2    | 0    | 2    | 1    | 0    |
| Maldives                      |      |      | 2    |      | 0    | 0    | 0    | 1    | 1    | 1    |
| Greece                        |      |      | 1    | 0    |      | 1    | 1    | 0    | 1    | 1    |
| New Zealand                   |      |      |      |      | 0    | 0    | 0    | 0    | 4    | 0    |
| Kuwait                        |      |      | 1    | 1    | 1    | 0    | 0    | 0    |      | 0    |
| Italy                         |      |      | 0    | 0    | 0    | 0    | 0    | 0    | 1    | 1    |
| Sweden                        |      |      |      |      |      |      | 0    | 0    | 1    | 3    |
| Grenada                       | 0    | 1    | 2    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| Netherlands                   |      |      |      |      | 1    | 1    | 0    | 0    | 0    | 0    |
| Solomon Islands               | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 1    |
| Comoros                       | 0    | 0    | 0    | 0    | 0    | 1    | 0    | 1    | 0    | 0    |
| Australia                     |      |      | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 1    |
| Bhutan                        | 1    |      |      | 0    |      | 0    | 0    | 0    | 0    | 1    |
| Equatorial Guinea             | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| Switzerland                   |      | 0    |      | 0    |      | 0    | 0    | 0    | 0    |      |
| Seychelles                    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| St. Vincent and<br>Grenadines |      |      | 0    | 0    |      |      | 0    | 0    | 0    |      |
| Antigua and<br>Barbuda        |      |      | 0    | 0    |      |      | 0    | 0    | 0    | 0    |
| Denmark                       |      |      |      |      |      |      | 0    | 0    |      | 0    |
| Norway                        |      |      | 0    |      |      | 0    | 0    |      | 0    | 0    |
| Dominica                      |      |      | 0    | 0    | 0    |      | 0    | 0    |      |      |
| Brunei                        |      |      | 0    | 0    |      |      |      | 0    | 0    | 0    |
| Finland                       |      |      |      |      |      |      |      |      | 0    |      |
| Germany                       |      |      | 0    |      |      | 0    | 0    | 0    |      | 0    |
| Iceland                       |      |      |      |      |      |      |      | 0    |      | 0    |
| St. Kitts and Nevis           |      |      |      | 0    |      |      |      |      |      |      |
| St. Lucia                     |      |      | 0    |      | 0    | 0    |      |      |      | 0    |
| Vietnam                       |      |      |      |      |      |      |      |      |      |      |

Adapted from: Greenbook. (n.d.). Retrieved April 3, 2015 from <https://explorer.usaid.gov/reports-greenbook.html>

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## APPENDIX B. UNITED NATIONS STATISTICS DIVISION RAW DATA

Table 7. Ten-Year Climatological Data

| Country                  | No. of events | Persons affected |
|--------------------------|---------------|------------------|
|                          | 2000-2009     | 2000-2009        |
| Afghanistan              | 6             | 4 960 000        |
| Albania                  | 3             | 150              |
| Algeria                  | 3             | 0                |
| Angola                   | 2             | 25 000           |
| Antigua and Barbuda      | 0             | 0                |
| Argentina                | 8             | 3 500            |
| Armenia                  | 1             | 297 000          |
| Australia                | 12            | 16 754           |
| Austria                  | 3             | 0                |
| Azerbaijan               | 1             | 0                |
| Bangladesh               | 8             | 151 000          |
| Belarus                  | 2             | 0                |
| Belgium                  | 5             | 0                |
| Belize                   | 0             | 0                |
| Benin                    | 0             | 0                |
| Bhutan                   | 0             | 0                |
| Bolivia                  | 7             | 103 277          |
| Bosnia and Herzegovina   | 5             | 72 575           |
| Botswana                 | 1             | 0                |
| Brazil                   | 7             | 2 000 000        |
| Brunei Darussalam        | 0             | 0                |
| Bulgaria                 | 10            | 0                |
| Burkina Faso             | 1             | 0                |
| Burundi                  | 3             | 2 232 500        |
| Cambodia                 | 3             | 1 550 000        |
| Cameroon                 | 2             | 0                |
| Canada                   | 5             | 1 800            |
| Cape Verde               | 1             | 30 000           |
| Central African Republic | 1             | 0                |
| Chad                     | 1             | 800 000          |
| Chile                    | 6             | 25 000           |
| China                    | 19            | 254 664 000      |
| China, Hong Kong SAR     | 0             | 0                |
| Colombia                 | 1             | 0                |
| Comoros                  | 0             | 0                |

| Country                    | No. of events | Persons affected |
|----------------------------|---------------|------------------|
| Congo                      | 0             | 0                |
| Costa Rica                 | 0             | 0                |
| Cote d'Ivoire              | 0             | 0                |
| Croatia                    | 8             | 0                |
| Cuba                       | 2             | 0                |
| Cyprus                     | 4             | 0                |
| Czech Republic             | 2             | 0                |
| Dem. Rep. of the Congo     | 0             | 0                |
| Denmark                    | 0             | 0                |
| Djibouti                   | 4             | 632 750          |
| Dominican Republic         | 1             | 0                |
| Ecuador                    | 0             | 0                |
| Egypt                      | 1             | 0                |
| El Salvador                | 2             | 400 000          |
| Eritrea                    | 1             | 1 700 000        |
| Estonia                    | 1             | 0                |
| Ethiopia                   | 4             | 21 600 000       |
| Fiji                       | 0             | 0                |
| France                     | 8             | 3 000            |
| Gambia                     | 1             | 0                |
| Georgia                    | 1             | 696 000          |
| Germany                    | 5             | 0                |
| Ghana                      | 0             | 0                |
| Greece                     | 6             | 1 593            |
| Guatemala                  | 4             | 115 446          |
| Guinea                     | 1             | 0                |
| Guinea-Bissau              | 2             | 132 000          |
| Guyana                     | 0             | 0                |
| Haiti                      | 1             | 35 000           |
| Honduras                   | 5             | 415 625          |
| Hungary                    | 5             | 0                |
| India                      | 18            | 350 000 000      |
| Indonesia                  | 5             | 15 000           |
| Iran (Islamic Republic of) | 1             | 0                |
| Iraq                       | 0             | 0                |
| Israel                     | 1             | 0                |
| Italy                      | 5             | 0                |
| Jamaica                    | 1             | 0                |
| Japan                      | 3             | 222              |
| Jordan                     | 2             | 150 000          |
| Kazakhstan                 | 1             | 0                |
| Kenya                      | 3             | 7 200 000        |

| Country                         | No. of events | Persons affected |
|---------------------------------|---------------|------------------|
| Kiribati                        | 0             | 0                |
| Korea, Republic of              | 4             | 3 800            |
| Kyrgyzstan                      | 1             | 0                |
| Lao People's Dem. Rep.          | 0             | 0                |
| Latvia                          | 3             | 0                |
| Lebanon                         | 1             | 0                |
| Lesotho                         | 2             | 975 000          |
| Liberia                         | 0             | 0                |
| Lithuania                       | 2             | 0                |
| Luxembourg                      | 1             | 0                |
| Madagascar                      | 3             | 845 290          |
| Malawi                          | 3             | 8 449 435        |
| Malaysia                        | 1             | 0                |
| Mali                            | 3             | 1 025 000        |
| Mauritania                      | 1             | 1 000 000        |
| Mauritius                       | 0             | 0                |
| Mexico                          | 6             | 0                |
| Micronesia, Federated States of | 0             | 0                |
| Mongolia                        | 1             | 450 000          |
| Morocco                         | 1             | 0                |
| Mozambique                      | 7             | 3 239 500        |
| Myanmar                         | 0             | 0                |
| Namibia                         | 2             | 345 000          |
| Nepal                           | 3             | 200 000          |
| Netherlands                     | 4             | 0                |
| New Zealand                     | 1             | 0                |
| Nicaragua                       | 3             | 204 000          |
| Niger                           | 2             | 6 584 558        |
| Nigeria                         | 1             | 0                |
| Pakistan                        | 7             | 0                |
| Panama                          | 1             | 1 436            |
| Papua New Guinea                | 0             | 0                |
| Paraguay                        | 6             | 380 990          |
| Peru                            | 6             | 3 083 427        |
| Philippines                     | 2             | 0                |
| Poland                          | 5             | 0                |
| Portugal                        | 8             | 150 000          |
| Puerto Rico                     | 0             | 0                |
| Republic of Moldova             | 3             | 210 394          |
| Romania                         | 11            | 0                |
| Russian Federation              | 21            | 1 031 000        |

| Country                               | No. of events | Persons affected |
|---------------------------------------|---------------|------------------|
| Rwanda                                | 1             | 1 000 000        |
| Samoa                                 | 0             | 0                |
| Sao Tome and Principe                 | 0             | 0                |
| Senegal                               | 1             | 284 000          |
| Serbia                                | 2             | 0                |
| Slovakia                              | 4             | 0                |
| Slovenia                              | 1             | 0                |
| Solomon Islands                       | 0             | 0                |
| Somalia                               | 4             | 4 700 000        |
| South Africa                          | 8             | 15 001 000       |
| Spain                                 | 9             | 1 200            |
| Sri Lanka                             | 1             | 1 000 000        |
| Sudan                                 | 1             | 2 000 000        |
| Swaziland                             | 3             | 1 381 500        |
| Sweden                                | 1             | 0                |
| Switzerland                           | 3             | 0                |
| Syrian Arab Republic                  | 1             | 1 000 000        |
| Tajikistan                            | 3             | 5 800 000        |
| Thailand                              | 4             | 15 000 000       |
| The Former Yugoslav Rep. of Macedonia | 5             | 1 000 202        |
| Timor-Leste                           | 1             | 0                |
| Togo                                  | 0             | 0                |
| Tunisia                               | 0             | 0                |
| Turkey                                | 8             | 0                |
| Uganda                                | 3             | 2 005 000        |
| Ukraine                               | 3             | 50 000           |
| United Kingdom                        | 3             | 0                |
| United Rep. of Tanzania               | 2             | 2 154 000        |
| United States                         | 46            | 786 526          |
| Uruguay                               | 3             | 2 400            |
| Uzbekistan                            | 1             | 600 000          |
| Viet Nam                              | 3             | 1 710 000        |
| Zambia                                | 1             | 1 200 000        |
| Zimbabwe                              | 2             | 8 100 000        |

Adapted from: Climatological disasters, 2010. Retrieved October 21, 2014, from [http://unstats.un.org/unsd/environment/Climatological\\_disasters.htm](http://unstats.un.org/unsd/environment/Climatological_disasters.htm)

Table 8. Ten-Year Geophysical Data

| <b>Country</b>         | <b>No. of events</b> | <b>Persons affected</b> |
|------------------------|----------------------|-------------------------|
|                        | <b>2000-2009</b>     | <b>2000-2009</b>        |
| Afghanistan            | 12                   | 90 740                  |
| Albania                | 1                    | 0                       |
| Algeria                | 5                    | 160                     |
| American Samoa         | 1                    | 2 500                   |
| Argentina              | 2                    | 500                     |
| Armenia                | 0                    | 0                       |
| Australia              | 0                    | 0                       |
| Austria                | 0                    | 0                       |
| Azerbaijan             | 1                    | 2 694                   |
| Bangladesh             | 3                    | 3 500                   |
| Barbados               | 1                    | 0                       |
| Belgium                | 0                    | 0                       |
| Bhutan                 | 1                    | 0                       |
| Bolivia                | 0                    | 0                       |
| Brazil                 | 1                    | 280                     |
| Bulgaria               | 1                    | 525                     |
| Burundi                | 1                    | 0                       |
| Cameroon               | 0                    | 0                       |
| Cape Verde             | 0                    | 0                       |
| Chile                  | 4                    | 60 463                  |
| China                  | 48                   | 52 742 377              |
| Colombia               | 13                   | 146 967                 |
| Comoros                | 3                    | 284 000                 |
| Congo                  | 1                    | 0                       |
| Costa Rica             | 3                    | 128 842                 |
| Croatia                | 0                    | 0                       |
| Cuba                   | 0                    | 0                       |
| Cyprus                 | 0                    | 0                       |
| Dem. Rep. of the Congo | 3                    | 17 355                  |
| Dominica               | 1                    | 100                     |
| Dominican Republic     | 1                    | 2 000                   |
| Ecuador                | 7                    | 497 670                 |
| Egypt                  | 2                    | 250                     |
| El Salvador            | 5                    | 1 601 648               |
| Ethiopia               | 2                    | 11 000                  |
| Fiji                   | 0                    | 0                       |
| France                 | 0                    | 0                       |
| Georgia                | 2                    | 25 300                  |
| Germany                | 1                    | 150                     |

| Country                    | No. of events | Persons affected |
|----------------------------|---------------|------------------|
| Greece                     | 5             | 4 518            |
| Guadeloupe                 | 1             | 100              |
| Guam                       | 0             | 0                |
| Guatemala                  | 4             | 2 987            |
| Guinea                     | 0             | 0                |
| Honduras                   | 3             | 51 720           |
| Iceland                    | 2             | 129              |
| India                      | 4             | 5 012 599        |
| Indonesia                  | 49            | 6 412 196        |
| Iran (Islamic Republic of) | 24            | 660 787          |
| Iraq                       | 0             | 0                |
| Italy                      | 6             | 230              |
| Japan                      | 17            | 154 949          |
| Kazakhstan                 | 1             | 36 000           |
| Kenya                      | 1             | 0                |
| Kyrgyzstan                 | 3             | 15 000           |
| Lebanon                    | 0             | 0                |
| Liberia                    | 0             | 0                |
| Malawi                     | 2             | 0                |
| Malaysia                   | 1             | 0                |
| Maldives                   | 1             | 12 000           |
| Martinique                 | 1             | 0                |
| Mexico                     | 4             | 218 830          |
| Montserrat                 | 1             | 200              |
| Morocco                    | 1             | 0                |
| Mozambique                 | 1             | 0                |
| Myanmar                    | 1             | 12 500           |
| Nepal                      | 0             | 0                |
| Netherlands                | 0             | 0                |
| New Zealand                | 0             | 0                |
| Nicaragua                  | 1             | 1 785            |
| Pakistan                   | 6             | 1 151 699        |
| Panama                     | 2             | 1 000            |
| Papua New Guinea           | 11            | 45 299           |
| Peru                       | 7             | 888 911          |
| Philippines                | 9             | 330 400          |
| Poland                     | 0             | 0                |
| Romania                    | 0             | 0                |
| Russian Federation         | 6             | 17 273           |
| Rwanda                     | 2             | 1 535            |

| Country                            | No. of events | Persons affected |
|------------------------------------|---------------|------------------|
| Saint Lucia                        | 1             | 0                |
| Samoa                              | 1             | 5 275            |
| Seychelles                         | 1             | 4 760            |
| Slovenia                           | 1             | 600              |
| Solomon Islands                    | 1             | 2 375            |
| Somalia                            | 1             | 104 800          |
| South Africa                       | 1             | 0                |
| Spain                              | 0             | 0                |
| Sri Lanka                          | 1             | 516 130          |
| Sudan                              | 0             | 0                |
| Tajikistan                         | 6             | 29 588           |
| Thailand                           | 1             | 58 550           |
| Tonga                              | 1             | 500              |
| Trinidad and Tobago                | 0             | 0                |
| Turkey                             | 15            | 531 460          |
| Turkmenistan                       | 1             | 0                |
| Uganda                             | 0             | 0                |
| United Kingdom                     | 1             | 4 500            |
| United Rep. of Tanzania            | 5             | 5 750            |
| United States                      | 6             | 30 619           |
| Uzbekistan                         | 0             | 0                |
| Vanuatu                            | 7             | 19900            |
| Venezuela (Bolivarian Republic of) | 0             | 0                |
| Wallis and Futuna Islands          | 0             | 0                |
| Yemen                              | 1             | 0                |

Adapted from: Geophysical Disasters. (2010). Retrieved October 21, 2014, from [http://unstats.un.org/unsd/environment/Geophysical\\_disasters.htm](http://unstats.un.org/unsd/environment/Geophysical_disasters.htm)

Table 9. Ten-Year Hydrological Data

| Country                  | No. of events | Persons affected |
|--------------------------|---------------|------------------|
|                          | 2000-2009     | 2000-2009        |
| Afghanistan              | 45            | 435 796          |
| Albania                  | 4             | 80 884           |
| Algeria                  | 25            | 195 300          |
| American Samoa           | 1             | 0                |
| Angola                   | 21            | 783 328          |
| Anguilla                 | 0             | 0                |
| Argentina                | 20            | 707 610          |
| Armenia                  | 1             | 0                |
| Australia                | 21            | 35 360           |
| Austria                  | 7             | 61 416           |
| Azerbaijan               | 3             | 35 000           |
| Bahamas                  | 0             | 0                |
| Bangladesh               | 23            | 58 601 793       |
| Barbados                 | 0             | 0                |
| Belarus                  | 0             | 0                |
| Belgium                  | 6             | 2 610            |
| Belize                   | 1             | 38 000           |
| Benin                    | 4             | 287 884          |
| Bhutan                   | 2             | 0                |
| Bolivia                  | 13            | 1 431 485        |
| Bosnia and Herzegovina   | 7             | 294 230          |
| Botswana                 | 4             | 116 392          |
| Brazil                   | 39            | 4 055 552        |
| Bulgaria                 | 11            | 13 260           |
| Burkina Faso             | 8             | 259 640          |
| Burundi                  | 16            | 28 965           |
| Cambodia                 | 8             | 6 644 182        |
| Cameroon                 | 6             | 24 500           |
| Canada                   | 18            | 16 070           |
| Cape Verde               | 1             | 0                |
| Central African Republic | 6             | 6 000            |
| Chad                     | 8             | 363 883          |
| Chile                    | 14            | 641 570          |
| China                    | 124           | 525 648 482      |

| Country                | No. of events | Persons affected |
|------------------------|---------------|------------------|
| China, Hong Kong SAR   | 1             | 0                |
| Colombia               | 34            | 4 488 763        |
| Comoros                | 1             | 2 500            |
| Congo                  | 4             | 25 000           |
| Costa Rica             | 14            | 284 189          |
| Cote d'Ivoire          | 3             | 2 450            |
| Croatia                | 4             | 2 050            |
| Cuba                   | 6             | 75 775           |
| Czech Republic         | 6             | 218 765          |
| Dem. Rep. of the Congo | 12            | 31 370           |
| Djibouti               | 1             | 98 500           |
| Dominican Republic     | 9             | 110 965          |
| Ecuador                | 11            | 413 630          |
| Egypt                  | 2             | 800              |
| El Salvador            | 8             | 7 332            |
| Eritrea                | 2             | 7 000            |
| Ethiopia               | 24            | 1 220 949        |
| Fiji                   | 7             | 12 280           |
| Finland                | 1             | 400              |
| France                 | 18            | 53 661           |
| French Guiana          | 0             | 0                |
| French Polynesia       | 0             | 0                |
| Gabon                  | 0             | 0                |
| Gambia                 | 4             | 14 808           |
| Georgia                | 4             | 3 100            |
| Germany                | 6             | 331 450          |
| Ghana                  | 7             | 691 345          |
| Greece                 | 14            | 12 180           |
| Guadeloupe             | 0             | 0                |
| Guatemala              | 14            | 314 356          |
| Guinea                 | 5             | 286 085          |
| Guinea-Bissau          | 3             | 0                |
| Guyana                 | 4             | 409 774          |
| Haiti                  | 20            | 355 119          |
| Honduras               | 9             | 334 275          |

| Country                    | No. of events | Persons affected |
|----------------------------|---------------|------------------|
| Hungary                    | 8             | 45 814           |
| Iceland                    | 0             | 0                |
| India                      | 109           | 238 302 253      |
| Indonesia                  | 88            | 3 685 941        |
| Iran (Islamic Republic of) | 22            | 1 412 850        |
| Iraq                       | 5             | 70 890           |
| Ireland                    | 2             | 300              |
| Israel                     | 0             | 0                |
| Italy                      | 17            | 58 000           |
| Jamaica                    | 2             | 30 000           |
| Japan                      | 12            | 455 028          |
| Jordan                     | 0             | 0                |
| Kazakhstan                 | 5             | 44 168           |
| Kenya                      | 30            | 1 246 738        |
| Kiribati                   | 1             | 0                |
| Korea, Dem. People's Rep.  | 9             | 1 203 630        |
| Korea, Republic of         | 11            | 337 831          |
| Kuwait                     | 0             | 0                |
| Kyrgyzstan                 | 7             | 1 481            |
| Lao People's Dem. Rep.     | 5             | 1 257 190        |
| Lebanon                    | 1             | 17 000           |
| Lesotho                    | 0             | 0                |
| Liberia                    | 3             | 17 584           |
| Libyan Arab Jamahiriya     | 0             | 0                |
| Lithuania                  | 1             | 0                |
| Luxembourg                 | 0             | 0                |
| Madagascar                 | 4             | 111 488          |
| Malawi                     | 15            | 1 159 276        |
| Malaysia                   | 24            | 369 564          |
| Maldives                   | 1             | 1 649            |
| Mali                       | 11            | 89 071           |
| Marshall Islands           | 1             | 600              |
| Mauritania                 | 9             | 98 120           |
| Mexico                     | 28            | 1 893 220        |

| Country                         | No. of events | Persons affected |
|---------------------------------|---------------|------------------|
| Micronesia, Federated States of | 1             | 0                |
| Mongolia                        | 3             | 15 500           |
| Montenegro                      | 2             | 1 536            |
| Morocco                         | 12            | 57 850           |
| Mozambique                      | 15            | 6 212 111        |
| Myanmar                         | 9             | 223 668          |
| Namibia                         | 9             | 474 300          |
| Nepal                           | 16            | 2 277 432        |
| Netherlands                     | 0             | 0                |
| New Zealand                     | 6             | 6 850            |
| Nicaragua                       | 8             | 66 866           |
| Niger                           | 7             | 222 549          |
| Nigeria                         | 28            | 532 865          |
| Norway                          | 2             | 2 100            |
| Occupied Palestinian Territory  | 1             | 0                |
| Pakistan                        | 41            | 9 562 094        |
| Panama                          | 15            | 89 097           |
| Papua New Guinea                | 11            | 89 256           |
| Paraguay                        | 2             | 14 800           |
| Peru                            | 20            | 659 997          |
| Philippines                     | 51            | 4 319 639        |
| Poland                          | 5             | 19 850           |
| Portugal                        | 5             | 348              |
| Puerto Rico                     | 3             | 11 705           |
| Republic of Moldova             | 3             | 11 000           |
| Romania                         | 32            | 202 778          |
| Russian Federation              | 32            | 872 104          |
| Rwanda                          | 8             | 40 795           |
| Saint Kitts and Nevis           | 0             | 0                |
| Saint Lucia                     | 0             | 0                |
| Samoa                           | 1             | 0                |
| Saudi Arabia                    | 7             | 13 450           |
| Senegal                         | 7             | 523 177          |
| Serbia                          | 2             | 15 580           |
| Seychelles                      | 0             | 0                |

| Country                               | No. of events | Persons affected |
|---------------------------------------|---------------|------------------|
| Sierra Leone                          | 4             | 20 955           |
| Slovakia                              | 6             | 330              |
| Slovenia                              | 1             | 0                |
| Solomon Islands                       | 2             | 7 000            |
| Somalia                               | 19            | 713 550          |
| South Africa                          | 14            | 118 116          |
| Spain                                 | 8             | 6 030            |
| Sri Lanka                             | 17            | 3 737 043        |
| St. Vincent and the Grenadines        | 0             | 0                |
| Sudan                                 | 13            | 1 408 246        |
| Suriname                              | 2             | 31 548           |
| Swaziland                             | 2             | 274 500          |
| Sweden                                | 0             | 0                |
| Switzerland                           | 6             | 7 381            |
| Syrian Arab Republic                  | 2             | 0                |
| Tajikistan                            | 21            | 470 664          |
| Thailand                              | 33            | 13 013 634       |
| The Former Yugoslav Rep. of Macedonia | 6             | 109 750          |
| Timor-Leste                           | 5             | 4 505            |
| Togo                                  | 4             | 174 615          |
| Trinidad and Tobago                   | 1             | 1 200            |
| Tunisia                               | 5             | 33 500           |
| Turkey                                | 22            | 111 476          |
| Turkmenistan                          | 0             | 0                |
| Uganda                                | 14            | 489 066          |
| Ukraine                               | 6             | 538 665          |
| United Kingdom                        | 15            | 350 830          |
| United Rep. of Tanzania               | 12            | 71 248           |
| United States                         | 57            | 11 317 806       |
| Uruguay                               | 7             | 142 200          |
| Uzbekistan                            | 1             | 1 500            |
| Vanuatu                               | 2             | 3 950            |

| Country                            | No. of events | Persons affected |
|------------------------------------|---------------|------------------|
| Venezuela (Bolivarian Republic of) | 12            | 128 421          |
| Viet Nam                           | 41            | 10 961 710       |
| Yemen                              | 16            | 28075            |
| Zambia                             | 11            | 3013620          |
| Zimbabwe                           | 5             | 265 000          |

Adapted from: Hydrological disasters. (2010). Retrieved October 21, 2014, from [http://unstats.un.org/unsd/environment/Hydro\\_disasters.htm](http://unstats.un.org/unsd/environment/Hydro_disasters.htm)

Table 10. Ten-Year Meteorological Data

| Country                | No. of events | Persons affected |
|------------------------|---------------|------------------|
|                        | 2000-2009     | 2000-2009        |
| Afghanistan            | 4             | 193 158          |
| Albania                | 2             | 525 000          |
| Algeria                | 3             | 0                |
| American Samoa         | 2             | 20 000           |
| Anguilla               | 0             | 0                |
| Antigua and Barbuda    | 1             | 25 800           |
| Argentina              | 8             | 6 400            |
| Australia              | 26            | 35 665           |
| Austria                | 6             | 300              |
| Bahamas                | 8             | 20 500           |
| Bangladesh             | 40            | 13 096 657       |
| Barbados               | 2             | 0                |
| Belarus                | 1             | 0                |
| Belgium                | 3             | 0                |
| Belize                 | 7             | 112 000          |
| Benin                  | 1             | 800              |
| Bermuda                | 1             | 0                |
| Bhutan                 | 1             | 0                |
| Bolivia                | 2             | 18 740           |
| Bosnia and Herzegovina | 1             | 0                |
| Botswana               | 1             | 400              |
| Brazil                 | 5             | 151 850          |
| British Virgin Islands | 0             | 0                |

| Country                  | No. of events | Persons affected |
|--------------------------|---------------|------------------|
| Bulgaria                 | 2             | 0                |
| Burundi                  | 3             | 0                |
| Cambodia                 | 2             | 178 000          |
| Canada                   | 11            | 500              |
| Cape Verde               | 0             | 0                |
| Cayman Islands           | 7             | 300              |
| Central African Republic | 3             | 9 137            |
| Chad                     | 1             | 0                |
| Chile                    | 2             | 2 112            |
| China                    | 85            | 279 159 647      |
| China, Hong Kong SAR     | 6             | 3 800            |
| China, Macao SAR         | 0             | 0                |
| Colombia                 | 2             | 3 074            |
| Comoros                  | 1             | 0                |
| Cook Islands             | 2             | 1 344            |
| Costa Rica               | 3             | 56 074           |
| Croatia                  | 1             | 0                |
| Cuba                     | 14            | 9 721 908        |
| Cyprus                   | 2             | 0                |
| Czech Republic           | 6             | 0                |
| Dem. Rep. of the Congo   | 5             | 75 000           |
| Denmark                  | 3             | 0                |
| Djibouti                 | 0             | 0                |
| Dominica                 | 2             | 7 675            |
| Dominican Republic       | 12            | 185 183          |
| Egypt                    | 1             | 0                |
| El Salvador              | 6             | 150 541          |
| Eritrea                  | 0             | 0                |
| Estonia                  | 1             | 100              |
| Fiji                     | 8             | 39 082           |
| Finland                  | 0             | 0                |
| France                   | 17            | 4 150            |
| French Polynesia         | 0             | 0                |

| Country                    | No. of events | Persons affected |
|----------------------------|---------------|------------------|
| Gabon                      | 1             | 0                |
| Gambia                     | 4             | 16 675           |
| Georgia                    | 1             | 900              |
| Germany                    | 16            | 0                |
| Greece                     | 4             | 600              |
| Grenada                    | 2             | 61 650           |
| Guadeloupe                 | 1             | 0                |
| Guam                       | 4             | 10 544           |
| Guatemala                  | 5             | 486 768          |
| Guinea                     | 1             | 0                |
| Guinea-Bissau              | 0             | 0                |
| Haiti                      | 18            | 706 756          |
| Honduras                   | 7             | 184 420          |
| Hungary                    | 3             | 0                |
| India                      | 29            | 5 475 905        |
| Indonesia                  | 2             | 3 715            |
| Iran (Islamic Republic of) | 5             | 170 500          |
| Ireland                    | 4             | 200              |
| Israel                     | 1             | 410              |
| Italy                      | 3             | 0                |
| Jamaica                    | 12            | 398 016          |
| Japan                      | 34            | 966 641          |
| Jordan                     | 2             | 0                |
| Kazakhstan                 | 0             | 0                |
| Kenya                      | 0             | 0                |
| Korea, Dem. People's Rep.  | 3             | 487401           |
| Korea, Republic of         | 15            | 154 725          |
| Kyrgyzstan                 | 1             | 9 075            |
| Lao People's Dem. Rep.     | 1             | 128 796          |
| Latvia                     | 2             | 0                |
| Lebanon                    | 1             | 500              |
| Lesotho                    | 3             | 5 500            |
| Liberia                    | 1             | 0                |
| Lithuania                  | 1             | 0                |
| Luxembourg                 | 0             | 0                |
| Madagascar                 | 22            | 3 193 291        |
| Malawi                     | 1             | 0                |

| Country                         | No. of events | Persons affected |
|---------------------------------|---------------|------------------|
| Malaysia                        | 4             | 41 655           |
| Maldives                        | 0             | 0                |
| Marshall Islands                | 0             | 0                |
| Martinique                      | 1             | 0                |
| Mauritania                      | 0             | 0                |
| Mauritius                       | 2             | 0                |
| Mexico                          | 27            | 4 279 471        |
| Micronesia, Federated States of | 4             | 7 300            |
| Mongolia                        | 6             | 1 911 000        |
| Montserrat                      | 0             | 0                |
| Morocco                         | 1             | 0                |
| Mozambique                      | 9             | 351 650          |
| Myanmar                         | 3             | 2 460 075        |
| Nepal                           | 0             | 0                |
| Netherlands                     | 4             | 0                |
| Netherlands Antilles            | 0             | 0                |
| New Caledonia                   | 1             | 0                |
| New Zealand                     | 4             | 400              |
| Nicaragua                       | 10            | 269 379          |
| Niger                           | 1             | 1 250            |
| Nigeria                         | 1             | 0                |
| Niue                            | 1             | 200              |
| Northern Mariana Islands        | 1             | 0                |
| Norway                          | 2             | 0                |
| Oman                            | 3             | 20 050           |
| Pakistan                        | 5             | 1 650 000        |
| Panama                          | 0             | 0                |
| Papua New Guinea                | 1             | 162 140          |
| Paraguay                        | 3             | 48 355           |
| Peru                            | 1             | 86 682           |
| Philippines                     | 81            | 45 118 831       |
| Poland                          | 8             | 1 050            |
| Portugal                        | 1             | 0                |
| Puerto Rico                     | 4             | 3 500            |

| Country                               | No. of events | Persons affected |
|---------------------------------------|---------------|------------------|
| Republic of Moldova                   | 1             | 2 600 000        |
| Réunion                               | 3             | 0                |
| Romania                               | 6             | 2 490            |
| Russian Federation                    | 12            | 18 000           |
| Saint Helena                          | 1             | 300              |
| Saint Kitts and Nevis                 | 0             | 0                |
| Saint Lucia                           | 2             | 0                |
| Samoa                                 | 2             | 0                |
| Saudi Arabia                          | 0             | 0                |
| Senegal                               | 1             | 0                |
| Seychelles                            | 1             | 6 800            |
| Sierra Leone                          | 0             | 0                |
| Slovakia                              | 1             | 10 300           |
| Slovenia                              | 2             | 0                |
| Solomon Islands                       | 3             | 275              |
| Somalia                               | 0             | 0                |
| South Africa                          | 11            | 101 150          |
| Spain                                 | 5             | 0                |
| Sri Lanka                             | 2             | 425 000          |
| St. Vincent and the Grenadines        | 2             | 1 000            |
| Sudan                                 | 1             | 0                |
| Swaziland                             | 2             | 7 425            |
| Sweden                                | 2             | 0                |
| Switzerland                           | 6             | 0                |
| Syrian Arab Republic                  | 2             | 0                |
| Tajikistan                            | 1             | 830              |
| Thailand                              | 11            | 85 869           |
| The Former Yugoslav Rep. of Macedonia | 1             | 0                |
| Timor-Leste                           | 1             | 8 730            |
| Tokelau                               | 1             | 0                |
| Tonga                                 | 2             | 16 500           |

| Country                            | No. of events | Persons affected |
|------------------------------------|---------------|------------------|
| Trinidad and Tobago                | 2             | 560              |
| Turkey                             | 5             | 1 500            |
| Turks and Caicos Islands           | 4             | 1 700            |
| Tuvalu                             | 0             | 0                |
| Uganda                             | 3             | 0                |
| Ukraine                            | 5             | 53 668           |
| United Kingdom                     | 9             | 23 280           |
| United Rep. of Tanzania            | 3             | 1 275            |
| United States                      | 129           | 8 598 206        |
| United States Virgin Islands       | 1             | 0                |
| Uruguay                            | 3             | 1 300            |
| Vanuatu                            | 3             | 54 505           |
| Venezuela (Bolivarian Republic of) | 1             | 1 645            |
| Viet Nam                           | 33            | 7 644 412        |
| Wallis and Futuna Islands          | 0             | 0                |
| Yemen                              | 2             | 0                |
| Zimbabwe                           | 2             | 0                |

Adapted from: Meteorological disasters. (2010). Retrieved October 21, 2014, from [http://unstats.un.org/unsd/environment/Meteo\\_disasters.htm](http://unstats.un.org/unsd/environment/Meteo_disasters.htm)

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